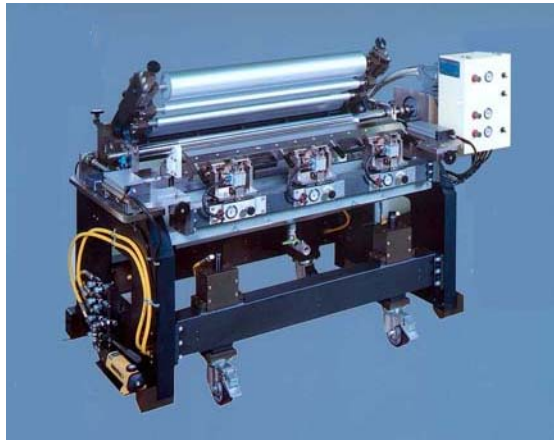


THE YASUI SEIKI "*Micro Gravure*<sup>™</sup>" COATING METHOD



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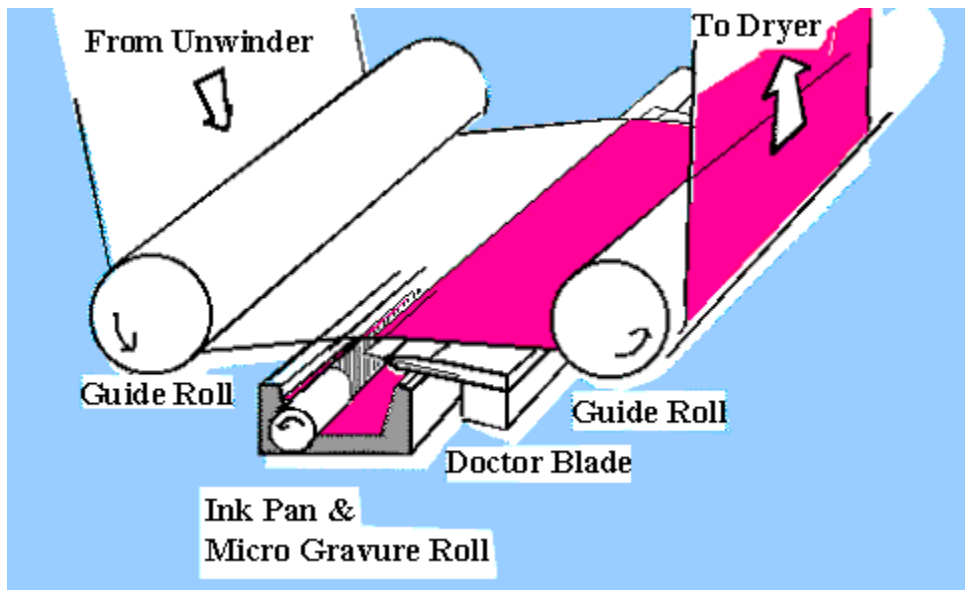
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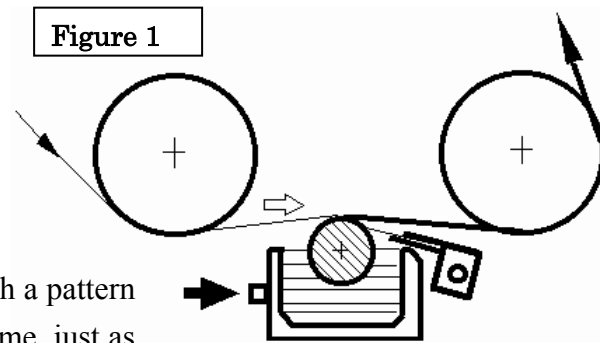


## INTRODUCTION

Many different types of coating systems are available, and in use today. Direct or reverse gravure, reverse roll, die coaters, wire bar, knife or blade coaters and many more are known and are widely used. All these techniques and more are offered by many machine manufacturers including **Yasui Seiki** Company.

However, many converters have reported disappointing results with techniques such as the wire bar and reverse roll. Many streaks with a wire bar and ‘orange peel’ with reverse roll, or creases caused by the backing roll of a gravure coater, troublesome changes of gravure roll and backing roll, and many other quality problems or difficulties are often reported.

The *Micro Gravure™* coating method was developed in response to the need for a smooth and uniform thin layer coating technique offering simplicity, reliability and reproducibility of coating. The *Micro Gravure™* method uses a gravure roll. The *Micro Gravure™* roll surface is engraved with a pattern or cells which provide a specific coating volume, just as



in standard gravure. The *Micro Gravure™* roll is mounted in bearings and rotates partially submerged in a coating pan. Rotation of the roll picks up the coating, which is doctored (pre-metered) by a flexible steel blade as the roll rotates toward the contact point with the web. [\(Fig.1\)](#)

## WHAT IS THE “*Micro Gravure™*” METHOD?

Generically described, this *Micro Gravure™* is a **reverse, kiss gravure** coating method. Standard gravure can be segregated into several types; direct and reverse are the two of greatest interest to this discussion. [\(Fig. 2\)](#) Typically, both of these types use a backing roll, usually rubber covered, and about the same diameter as the engraved roll. The web is trapped, or nipped, between the engraved roll and the backing roll. In addition to the obvious and frequently encountered problems of web creases or breaks, a nip point introduces a number of mechanical, hydraulic and other stresses which impact coating quality. *Micro Gravure™* is a kiss coating

method. “Kiss” implies the absence of a backing roll, which would trap the web against the engraved roll. Since *Micro Gravure™* is a kiss method, and does not use a nip, a number of these potentially deleterious stresses (and safety issues) are eliminated.

*Micro Gravure™* is a reverse process. That is to say that the rotational direction of the engraved cylinder is opposite to the travel direction of the web. The coating is thus applied to the web in a shearing manner, or the liquid coating is experiencing shear. If the web direction and the cylinder rotation are the same, the coating would be split apart; some would tend to go to the web, some would tend to stay on the cylinder. This condition is often described as “film splitting”. Depending on the strength of the internal forces in the coating itself, film splitting can be very disruptive. On the other hand, “shear” application is generally acknowledged to produce somewhat smoother coatings than “film splitting”.

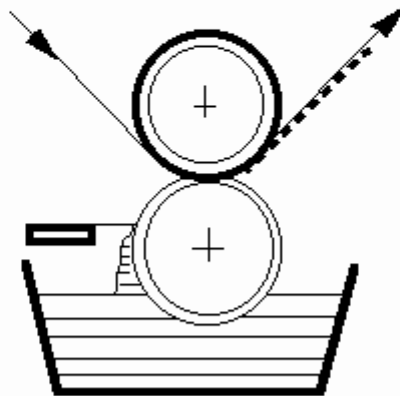
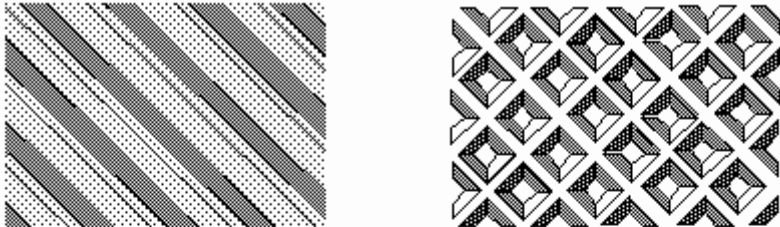


Figure 2

The Surface of the roll used in *Micro Gravure™* coating has a number of regularly spaced "cells" which determine a finite volume of internal capacity. The geometry, number and spacing, depth or other features of the cell can be varied to produce a range of total volume to accomplish coating weight (thickness) control. This logic is, of course, the same as in standard gravure. So, *Micro Gravure™* is a kind of gravure coating method.

### “*Micro Gravure™*” vs. OTHER METHODS

Therefore, what is the difference between this *Micro Gravure™* system and conventional ordinary direct or reverse gravure systems? There is, of course, a great difference between them.

The “Micro” reference is in regard to the **small physical diameter** of the engraved roll. In the case of conventional gravure coating methods, standard gravure roll diameters are typically in the range of 125 to 250mm. On the other hand, *Micro Gravure™* diameters are from 20mm to 50mm, determined by the coated width required. *Micro Gravure™* rolls are 20mm diameter for 300mm width and increase to 50mm diameter for coating widths of 1600mm. The small diameter produces a much smaller line of contact on the web at the point the web touches *Micro Gravure™* roll. This is easily visualized by two concentric circles with a pair of rays drawn from the center of each (Fig. 3). The arc on the circumference of the larger circle is obviously much greater than on the small circle. The total contact area of web and wet gravure roll has a certain criticality. In general, a larger contact area may exhibit coating problems to a much greater degree than a smaller contact area. The total area is a product of dimension in the transport direction and in the cross web direction. It is really the transport direction (the length of the contact) that is the critical factor. For a given set of conditions, a larger diameter roll will produce a longer line of contact than a smaller diameter. When a backing roll is introduced, this region of contact is increased even more.

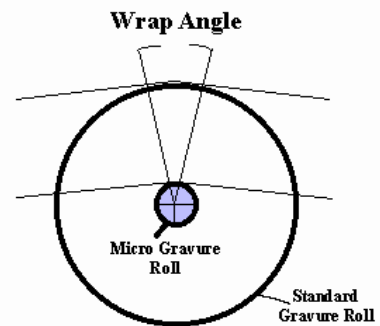
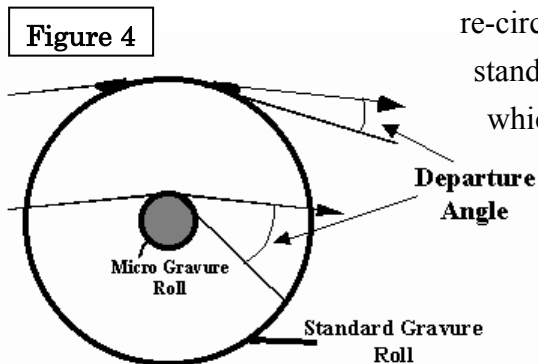


Figure 3

In the case of standard gravure, operating in the direct mode, the amount of the coating in the cells is divided. Some is transferred to the web and some part remains in the cell after the contact point has passed. Typically, there is established a reservoir of coating at both the entry point and the departure point of the nip. Within these two beads of coating, a pattern of turbulent re-circulation will occur. The large diameter rolls used in standard gravure can produce very large turbulent beads, which in turn create aberrations in the coating. (Fig. 4)



When nip roll pressure, skewness of rolls, or other mechanical factors are present, the situation is even more critical. In standard reverse gravure, particularly with a backing roll, much of the above holds true. In some cases a very large reservoir of coating at the web exit point can be generated. This is seriously influenced by abnormal or faulty condition of the backing roll. The absence of a backing roll

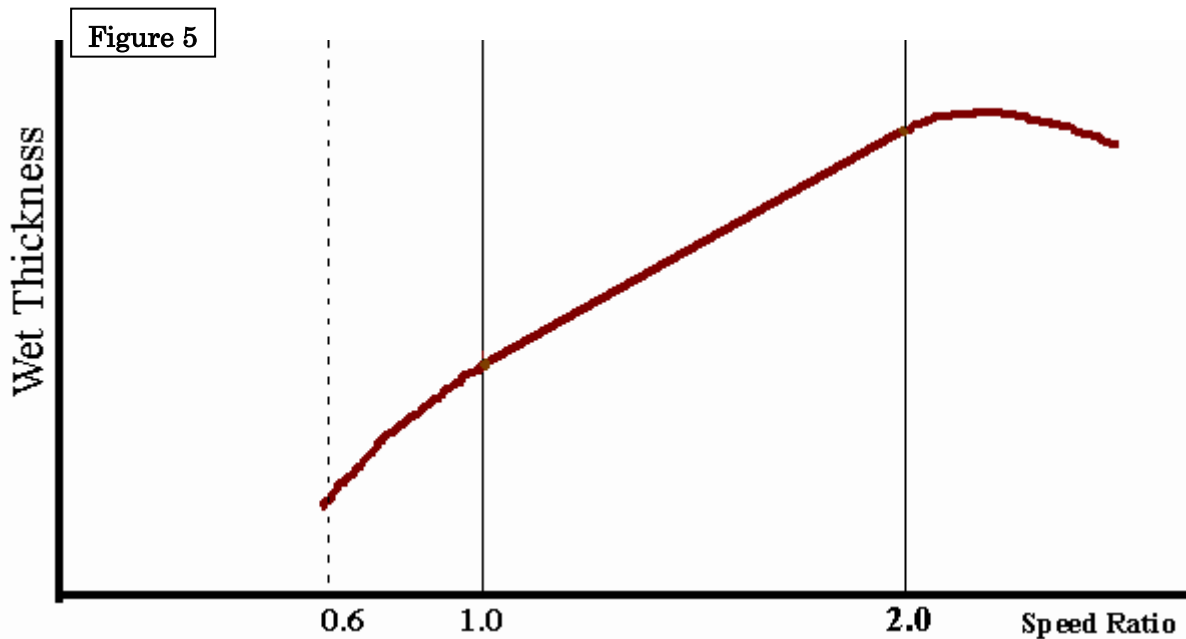
with *Micro Gravure™* reduces or eliminates many of the nip induced coating defects associated with other methods. The turbulent bead problem is also minimized because of the small diameter rolls used. The volume of the bead present on the entry and exit point is very small and stable.

Like any “gravure” or “engraved roll” system the *Micro Gravure™* system also requires two basic processes; introduction of coating to the roll surface, and a means of evenly and accurately metering the coating on the roll surface. A common method of coating application to the roll is a “pan” in which the roll rotates partially submerged. Since the amount of coating on the roll surface is largely dependent on viscosity, some metering means must be used. A blade, or knife is used to remove excess coating solution. Without this, the cell volume could not be the major factor in determining thickness or weight of the wet coating on the substrate. However, the blade used in *Micro Gravure™* is quite different from blades used in most gravure processes. The major departure relates to stiffness and the angle of attack of the blade to the roll surface. *Micro Gravure™* blades are quite thin and flexible in comparison to those typically used in gravure processes. The pressure of the blade against the roll is rather light. The angle of attack of a standard gravure blade is steep. The line of the blade extension typically passes close to the roll center. The thin, flexible *Micro Gravure™* blade lays on the roll, nearly tangent to the surface. The comparison here is a scraping action versus smoothing or metering. Standard Doctor metering can cause considerable wearing of blade and roll surface because of this scraping action. The life of both blade and roll is extended because of the more gentle contact inherent in the *Micro Gravure™* process.

### **OPERATION of “*Micro Gravure™*”**

As already mentioned, the *Micro Gravure™* roll is made with surface cells designed to produce a specific coating volume, just as in a standard gravure system. A wide range of patterns and cell volumes is available. The roll is mounted in bearings and is rotated by a small motor through a coupling. Direction of rotation is opposing that of web travel. As the roll rotates, it picks up coating in the ink pan. Continuing rotation takes the coating to the blade where a small excess amount is removed prior to the contact point with the web. The distance from coating impingement on the roll surface to web transfer point is less than a 90degree arc. The circumferential distance is about 30mm or less even for a 40mm diameter roll. [\(Fig.1\)](#)

The ratio of the web speed to circumferential speed of the engraved roll is critical in establishing coating thickness. (Fig. 5) At a given web speed with the cylinder stationary, no coating is transferred to the web. As rotational speed is increased, coating will start. Additional rotational speed increases the coating weight until flooding, or instability, and a decrease in coating weight occurs. Coating weight plotted against speed ratio will generally show a “hump back” or bell-shaped curve. The behavior of a “typical” coating will follow the pattern: 60% - coating starts, 100 to 130% - a smooth and uniform coating, 130 to 200% - weight increase, 200% or more – weight decrease and instability. If the web speed is 30m per minute and the cylinder’s surface speed is also 30m per minute, it is 100% or 1 to 1, and if the roll speed is 60m per minute for 30m per minute web speed, then it is 200% or 2 to 1 ratio. Although the cell volume is the major control of coating weight, a “window” will exist on the linear portion of the curve, usually between 100% and 130%, which will allow coating weight or thickness control, while maintaining a uniform appearance. In a very practical way, weight changes of perhaps +/-10% or more, can be made for each cylinder pattern. This can result in economy through requiring a fewer number of rolls to obtain particular weights. From the list of rolls shown in Table 1, it can be seen that it is possible to overlap adjacent rolls via the ratio change. In this way almost continuous changes in weight can be made. For critical applications a curve should be developed for each cell pattern and rheological combination.



A 1 to 1 ratio is a good starting point for examination of a new coating. Some 100% solids formulations have been seen to exhibit rather strange behavior relative to the “typical coating” with a 1 to 1 ratio, although it is really not surprising, to see a departure from a typical 30-40% solids solution chemistry. The *Micro Gravure™* system can easily respond via manipulation of the ratio. On occasion, a ratio of 2 to 1 or 3 to 1 has produced good coatings with 100% solids UV or radiation curables.

### ADVANTAGES of “*Micro Gravure™*”

*Micro Gravure™* can put down thinner coatings on thinner webs, than any other system. This is accomplished primarily because of the very small “footprint” of the web on the roll and because no backing roll is used. A nip point can cause breakage, wrinkles or folds in the web. As [Table 1](#) shows, a 250 mesh (250 cells per linear inch) gravure roll can produce a 1 micron thick wet coated layer. If the coating’s solid content is 5%, then the applied film is 0.05 micron thick after drying.

Since there is no backing roll, coating can be applied close to the film edge without concern for transfer to the backside of the film or to the backing roll. Film widths can be changed without having to change the backing roll, as would be required in standard gravure. A wide variety of thin films, papers, fabrics and foils can be easily accommodated. But, this does not mean that the *Micro Gravure™* system is only suitable for thin films, i.e. 2 micron PET. This system is also used for coating on 8 mil (200 micron) thick steel foil.

Wear of the doctor blade and of the engraved cylinder is minimized because of the light contact of blade and roll. The action is pre-metering rather than scraping.

The cost of the small diameter rolls is relatively low, so that many can be on hand without economic penalty. Because of the small size, quick changes of rolls can be made to change coating thickness. Speed ratio manipulation, as previously discussed, makes thickness changes possible as well.

Reverse or shearing application normally produces smooth coatings without the need for a post smoothing system. The small diameter also allows more volatile solvents to be used without danger of cell plugging. There is considerable flexibility in formulating for the system;



experience indicates a viable range of viscosity from 1 cps to 1000 cps and in some cases even to 2000 cps.

## SUMMARY

Very simply, regardless of whether for production use or for laboratory use a coating machine must satisfy such requirements as ‘Reliability’, ‘Reproducibility of coating’ and ‘Simplicity of operation’. The physical comparisons of *Micro Gravure™* to other roll coating processes show simplicity versus complexity. Machine construction is such that vibration, drive inconsistency, tension variation or similar problems do not arise to adversely effect coating quality. Particular attention is given to component selection such as: drive couplings, motors, tension controls and the like. Structural members are selected with regard to influence on the most sensitive coating methods. Sensible design and quality assembly of top grade components assures reliability and reproducibility. Simplicity of the *Micro Gravure™* system fosters simplicity of operation.

In the past 20 years, over 300 Yasui production coating lines, laboratory use coaters, and over 100 *Micro Gravure™* production coating stations have been sold all over the world to companies, such as Eastman Kodak, DuPont, 3M, JVC, Hitachi, Toshiba, Panasonic, Mitsubishi Chemical, Teijin, SKC, and many other leading companies in various industrial fields. Virtually all of our customers who replaced or supplemented their production system or laboratory use system with *Micro Gravure™* coaters produced better results than with their other production systems or research coaters. Especially when a smooth, uniform and very thin layer such as several or a few microns or even a few hundred angstroms is required, this *Micro Gravure™* system exhibits its capability.

**Yasui Seiki** Company does not wish to give the impression that the *Micro Gravure™* system can do anything and everything. Our experience indicates that in many cases improved coating quality can result from use of this technology for solvent and emulsion coatings or UV curables. We also do not imply that all other coating methods are categorically inferior to *Micro Gravure™*. We are certainly well aware that quality coatings are being made every day using a wide range of coating techniques....

**Table 1**

***Micro Gravure™*** Wet Coat weight Chart

<b>Mesh Lines/inch</b>	<b>Wet Coat Thickness <math>\mu</math> *</b>
25	50 - 80
30	30 - 45
36	28 - 43
38	25 - 40
45	28 - 43
50	25 - 35
55	20 - 30
60	21 - 31
65	13 - 22
70	16 - 30
75	20 - 30
80	12 - 20

<b>Mesh Lines/inch</b>	<b>Wet Coat Thickness <math>\mu</math> *</b>
85	13 - 22
90	8 - 16
95	7 - 15
100	6 - 14
110	6 - 13
120	5 - 11
150	4 - 9
180	3 - 8
200	2 - 5
230	1.5 - 3.5
250	0.8 - 2

Notes: \*Coat weight is controlled by speed ratio of Gravure speed  $\div$  web speed, in ranges shown